

Oil Crisis, Energy-Saving Technological Change and the Stock Market Collapse of the 70's*

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Abstract

The market value of U.S. corporations, relative to the replacement cost of their tangible assets, declined by about 50% in 1973-74, and stagnated at that level for the following decade. This collapse in market valuations exactly coincides with the Oil Crisis of October 1973. Over the 1973-78 period, the OPEC embargo translated into 44% increase in energy prices. This paper uses a calibrated dynamic general equilibrium model to quantitatively assess the impact of the energy price increase on the market valuation of U.S. corporations. The key features of the model are the technology-specific nature of capital, the

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irreversibility of investment decisions, and the induced innovation hypothesis. In the model, the arrival of a new energy-saving technology coincides with the increase in energy prices; rendering old capital obsolete, and its market value to collapse. In the data, the number of patents granted to energy-saving technologies increased in the mid 1970's, which gives empirical support to the induced innovation hypothesis. We find the observed changes in energy prices, together with the energy saving change implied in the observed energy output data, generate an 17% drop in Tobin's q ; slightly more than a third of what is observed in the data.

1 Introduction

Over the 1962-72 period the market value of U.S. corporations, relative to the replacement cost of their tangible assets (Tobin's average q) averaged 1.04. As can be seen in Figure 1, the ratio collapsed in 1973-74 and stagnated for the following decade. Over 1973-84 Tobin's q averaged 0.56, 46% less than its 1960-72 average.

This abrupt decline in market valuation coincides exactly with the increase in energy prices caused by the OPEC embargo, which was announced in early October of 1973. The largest drop in market values occurred in the 4th quarter of 1973, and throughout 1974. As shown in Figure 2, the price of energy relative to the GDP deflator increased by 37% over 1973-74, and continued rising up to 1981. By then energy prices were 2.2 times higher than in 1972. In 1982 they started declining but they have yet to come back to their 1972 level after 29 years.

In this paper, we use neoclassical growth theory to determine how much of the drop in corporate market valuation can be accounted for by changes in energy prices. Our tool of analysis is a dynamic general equilibrium model where capital is technology-specific, and investment decisions irreversible. These assumptions are standard in the literature (cf. Sargent [36], Dixit and Pyndick [9]), and allow for Tobin's q to fall below 1, as in the data.

As illustrated by Figure 3 below, the energy use of the business sector (as ratio to its output) was relatively constant over the 1960s but started

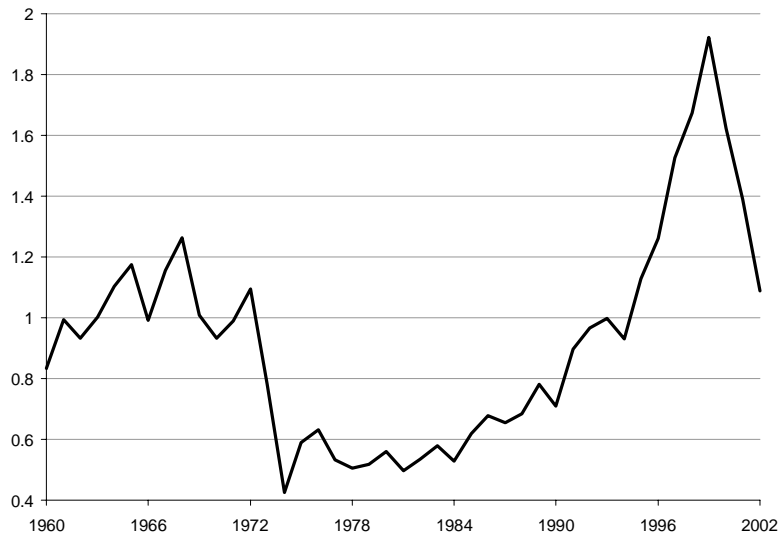


Figure 1: Market Value of US corporations as ratio of the replacement cost of their tangible assets

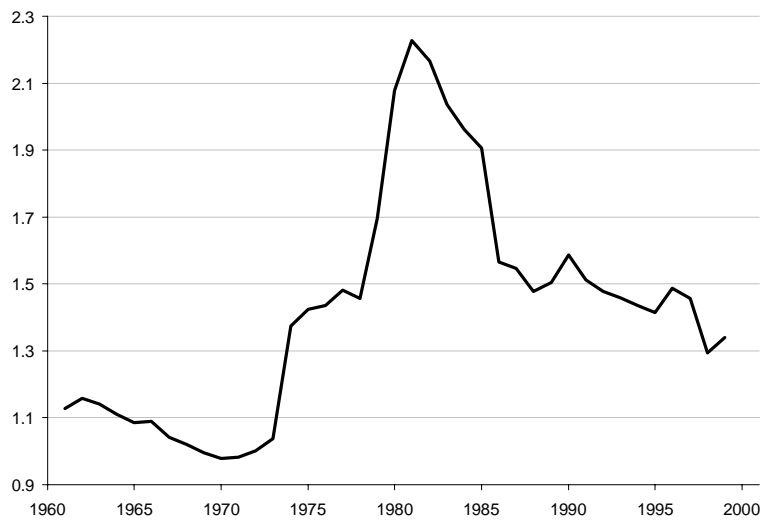


Figure 2: Energy prices relative to GDP deflator

declining steadily around 1974. Any model used to quantify the impact of changes in the energy sector on the stock market, we believe, has to be consistent with two important features of the data: The monotone decrease in the energy-output ratio, and the observed trends in energy prices. This requirement rules out some standard models of energy use, like the Putty-Clay model of Atkeson and Kehoe [2] or Wei [39], as they imply the energy output ratio should go up when energy prices decrease. To make our model consistent with the data, we introduce, simultaneous with the changes in energy prices, a new technology characterized by increasingly lower energy requirements (i.e. energy saving technological change). The empirical analysis of Popp [32] gives further support to this alternative hypothesis, as he finds the number of patents granted to energy-saving technologies increased right in the mid-1970s.

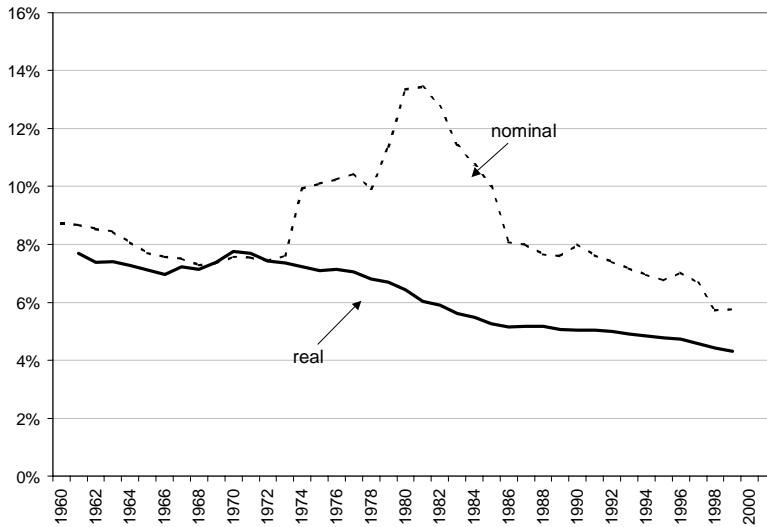


Figure 3: Energy use and expenditure in the business sector

In our model economy, the increase in energy prices, coupled with the availability of a new energy-efficient technology, causes investment in the old energy-inefficient technology to stop, and old capital is left to depreciate. This mechanism is in the spirit of Baily [3] who states that “when

major changes in factor prices occur and technology choice is embodied in the capital stock, structural change causes capital obsolescence". Old technologies are suddenly abandoned, the flow of dividends they generate declines abruptly, and this causes a collapse in their market valuation. Our results indicate the observed changes in energy prices, and the energy saving change implied by the patterns of the energy-output ratio, translate into an 17% drop in Tobin's q , slightly more than a third of the observed one.

Our paper is related to Wei [39]. She also studies the effects of the oil crisis of 1973 on the market value of U.S. corporations, and uses a general equilibrium model with putty-clay technology. In that framework an 80% temporary increase in energy prices can only account for a 2% drop in market valuations. The main differences between our paper and Wei [39] are as follows: First, her model is not consistent with the observed monotone decrease in energy use. New firms face an ex-ante Cobb-Douglas production function and thus, when energy prices go down, as in the US data over the 1980s, the model predicts a counterfactual increase in the energy output ratio. Second, she calculates the increase in energy prices using CPI data. However, the relevant measure for the question at hand is energy prices paid by business consumers of energy and not by household consumers. These measures seem to differ as the consumption weights of coal, natural gas, petroleum and electricity are surely different for businesses and households. Third, we allow labor to switch from the old technology to the new more energy-efficient technology as the old technology is gradually abandoned. Her assumption of fixed labor input in the old technology not only weakens her result, but also generates a counterfactual prediction for the share of income going to labor. In her model, as labor gets stuck in the old vintages the share of income going to labor drops. In the data however, the share of income in the corporate sector went down one percentage point only if at all.

Another explanation for the stock market collapse of the 1970's has been put forward by McGrattan & Prescott [27]. They argue that the increase in investment tax credits given to corporations in the 1970's contributed to the decline of market value, since this reduces the value of installed capital rela-

tive to its replacement cost. Although we do not think taxes and regulations are unimportant for the decline in market value, we nevertheless abstract from them in our model to concentrate on the effects of the oil crisis and energy-saving technological change.

Section 2 lays out the model. Section 3 discusses calibration, computation and findings. Section 4 concludes.

2 The Model

In this section we present a general equilibrium asset pricing model with production and capital accumulation. The economy is closed except for energy which is imported from abroad and paid in full every period with the domestic good. It follows that the current account is zero at all periods, and that there is no borrowing and lending from abroad. Initially, there is an unexpected and permanent rise in energy prices, and a new technology becomes available. After those changes everything in the model is deterministic.

There is a representative household whose preferences are described by

$$\sum_{t=0}^{\infty} (\beta \gamma_N)^t u(c_t)$$

, where c_t is per-capita consumption at period t , $u(\cdot)$ is strictly increasing, strictly concave and satisfies Inada conditions. γ_N is the growth factor in the number of household members. Each member of the household has one unit of time, and supplies it inelastically to the firm. The household participates in a market for shares. Owning a fraction s_t of the perfectly divisible share entitles them to the same fraction of the dividends paid by the firm. In summary, the household problem is to choose sequences of consumption $\{c_t\}$ and asset holdings $\{s_t\}$ that maximize utility subject to

$$\sum_{t=0}^{\infty} p_t [c_t + V_t (s_{t+1} - s_t)] = \sum_{t=0}^{\infty} p_t [w_t + d_t s_t]$$

$c_t, s_t \geq 0$ for all t , s_0 given

, where V_t is the price per share of the firm and d_t are the dividends received at period t .

There is a continuum of identical firms, which produce consumption and investment goods using capital, labor and energy as inputs. The firms own their capital, hire labor services and import energy from abroad. Before the shock, there is a single constant returns to scale technology available to the firm, which we label as 1. An unexpected shock occurs in 1973, which consists of a sudden increase in energy prices, and of the arrival of a second technology. This technology is more energy-efficient, in the sense that, other things equal, it requires less energy to produce the same amount of output. The outputs produced by each of the two technologies (or firms) are perfect substitutes for one another; however, capital is technology specific and capital installed in the old technology cannot be used in the new one. Due to investment irreversibility, it cannot be transformed to the consumption good either. The firm's problem is to choose sequences of investment $\{x_{it}\}$, labor $\{n_{it}\}$ and energy $\{e_{it}\}$ for $i = 1, 2$ so as to

$$\begin{aligned}
& \max_{\{x_i, n_i, e_i\}_{i \geq 0}} \sum_{t=0}^{\infty} p_t d_t \\
& \text{s.t.} \\
& d_t = y_t - w_t (n_{1t} + n_{2t}) - p_t^e (e_{1t} + e_{2t}) - x_{1t} - x_{2t} \\
& y_t = A_t F(k_{1t}, \xi e_{1t}, n_{1t}) + A_t F(k_{2t}, \phi_t e_{2t}, n_{2t}) \\
& x_{it} = k_{it+1} - (1 - \delta) k_{it} \quad \text{for } i = 1, 2 \\
& x_{it}, e_{it}, n_{it} \geq 0 \quad \text{for } i = 1, 2 \\
& n_{1t} + n_{2t} \leq 1, \quad \text{given } k_{10}, k_{20}
\end{aligned} \tag{1}$$

, where y_t is output, and p_t^e is the (relative) price of energy. A_t is the level of total factor productivity and grows at rate $\gamma_A - 1$. F is a neoclassical production function, ξ and $\{\phi_t\}$ are the parameters governing the energy-efficiency of each of the available technologies

The economy's resource constraint is now given by

$$c_t + x_{1t} + x_{2t} + p_t^e (e_{1t} + e_{2t}) = y_t, \quad \text{for all } t. \quad (2)$$

Note that the above specification dictates a balanced current account each period, where energy imports from abroad are paid off fully, and there is no foreign borrowing or lending. Finally, there is a market clearing condition for market for shares, which requires $s_t = 1$ for all t .

2.1 Tobin's (average) q

Tobin's average q is defined as the ratio of market value to the replacement cost of capital. In the model described above, market value corresponds to V_t . Furthermore, constraints (1) and (2) force the relative price of new capital to equal one, and thus the replacement cost of capital (at the end of period t) is $k_{1t+1} + k_{2t+1}$. Hence, Tobin's average q in this model is

$$q_t = \frac{V_t}{k_{1t+1} + k_{2t+1}}.$$

As is well known, a necessary condition for q to fall below one is that at least one of the irreversibility constraints has to bind. Intuitively, the increase in energy prices, together with the arrival of an energy saving technology, make the amount of old capital "too big." In a world where investment decisions are reversible, agents would transform capital into consumption, and restore the optimal capital levels. Irreversibility forbids them to do so, and the impact of this constraint on the utility of the households is exactly what determines the drop in the price of installed capital.

3 Calibration and Results

In this section we discuss how the model was calibrated and computed. Also we lay out the findings from the model and compare them with the data.

3.1 Calibration

We first choose specific utility and production functions and then calibrate the parameters of the model to match certain facts of the data as outlined in Cooley and Prescott [8].

For the utility function of the households, we use the standard constant relative risk aversion (or in this deterministic case constant intertemporal elasticity of substitution) utility function:

$$u(c) = \begin{cases} \frac{c^{1-\sigma}}{1-\sigma} & \text{for } \sigma \neq 1 \\ \log(c) & \text{for } \sigma = 1 \end{cases}$$

, where the intertemporal elasticity of substitution is given by $1/\sigma$. We interpret this as a model of the US corporate sector, and let

$$F(k, e, n) = (\min\{k, e\})^\alpha n^{1-\alpha}.$$

We calibrate the parameters of the model so that the balanced growth properties of the model, prior to the energy shock, match their counterparts in the data for the pre-crisis period. The balanced growth rate of per capita variables in this model economy is

$$\gamma = (\gamma_A)^{\frac{1}{1-\alpha}}$$

, and we calibrate γ to match the average postwar per-capita growth rate of U.S. corporate output which is 2%, and thus $\gamma=1.02$. α is calibrated to match one minus the labor share of income in total income in the corporate sector, obtaining a value for α of 0.36. σ governs the intertemporal elasticity of substitution and we take this number from Prescott [33], who makes a convincing case for unit elasticity and let $\sigma = 1$. We pick β and δ so that the model's capital output and interest rate match their data counterparts. The resulting parameters were $\beta = 0.96$ and $\delta = 0.11$. Finally, we set ξ so that the model's¹ energy use to output ratio matches the 1960-72 US average,

¹ Assuming technology two is not available, and that energy prices remain at their 1960-72 average

and compute the sequence $\{\phi_t\}_{t=1973}^{2001}$ that minimizes the distance between the equilibrium energy output ratio from the model, and the associated data series. The resulting sequence is plotted in Figure 4

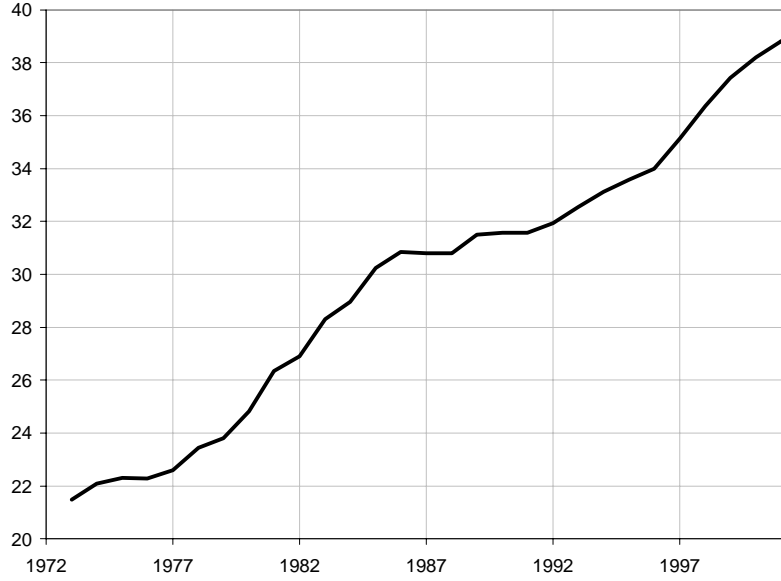


Figure 4: Energy saving technological change in the new technology

3.2 Computation

To make the model (eventually) stationary, we assume that both, the price of energy, p_t^e , and the energy saving parameter ϕ_t , remain at their year 2000 level for all $t \geq 2000$. We then compute and use the resulting (time stationary) value function, for all $t \geq 2000$, and solve by backwards induction for $1973 \leq t \leq 1999$. Since there are no distortions, we can use the second welfare theorem to solve for the equilibrium of this economy. The associated

dynamic programming problem is

$$\begin{aligned}
V_t(k_1, k_2, \phi_t, p_t^e) &= \max \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta \gamma^{-\sigma} V_{t+1}(k'_1, k'_2, \phi_{t+1}, p_{t+1}^e) \right\} \\
\text{s.t.} \\
c + x_1 + x_2 + p^e(e_1 + e_2) &= (\min\{k_1, \xi e_1\})^\alpha n^{1-\alpha} + (\min\{k_2, \phi_t e_2\})^\alpha (1-n)^{1-\alpha} \\
\gamma k'_1 &= x_1 + (1-\delta)k_1 \\
\gamma k'_2 &= x_2 + (1-\delta)k_2 \\
x_1, x_2 &\geq 0
\end{aligned}$$

, where all of the above variables have been detrended by their balanced growth rate. The computational algorithm used for approximating the solution to the previous problem was value function iteration. We assume the economy starts at the steady-state associated with the pre-energy crisis period over which technology 2 was not available. We let $k_{2,1973} = 0$. From then on there is perfect certainty about the sequences $\{p_t^e\}$ and $\{\phi_t\}$.

3.3 Findings

As previously described, the energy saving properties of the new technology make the model consistent with the observed energy output ratio: in spite of the sharp decreases in energy prices of the mid 1980s energy use declines monotonically, as in the data. The energy output ratio from the model and of the US corporate sector are summarized in Figure 5 below

The observed changes in energy prices, coupled with the availability of a new technology with energy saving factor $\{\phi\}$, translate into an 17% drop in market valuations, slightly more than one third of the observed one. The model's predictions for q , and its US data counter part are plotted below. Notice, though, that the model implies a smooth recovery in q while in the data it remained stagnant for almost a decade. Existing papers, based on technical change, for explaining the behavior of market valuations share this undesirable property (cf. Laitner and Stolyarov [24] or Jovanovic and Rosseau [21]).

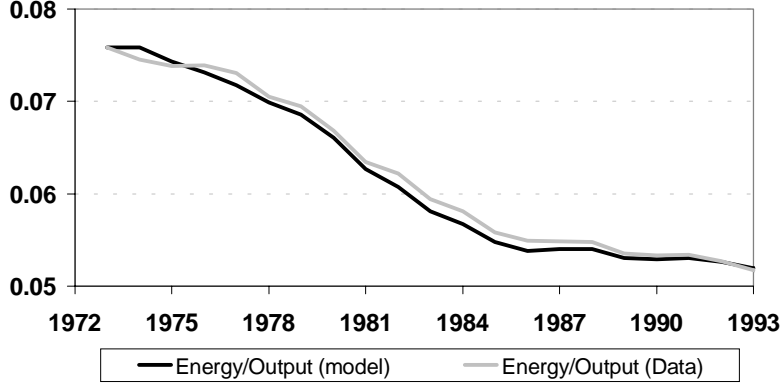


Figure 5: Energy to output: Model vs data

The increase in energy prices generates a slowdown in output slightly larger than the observed one, as the following graph illustrates . It also generates a strong contraction in investment. We believe the latter is due to the simplicity of our model. We have abstracted from changes in investment tax credits, from the impact of the productivity slowdown, and from the increasing importance of information technologies. All of those changes are known to make investment increase and, more importantly, to generate sudden drops in market valuations (cf. McGrattan and Prescott [27], Boldrin and Peralta-Alva [5], and Peralta-Alva[31]).

4 Conclusion

This paper employs a calibrated dynamic general equilibrium model to evaluate how much of the stock market collapse of 1973-74 can be accounted for by changes in energy prices. In a world where capital is technology specific, and investment decisions irreversible, we find that the observed changes in energy prices, together with the energy saving factor derived from the energy use series data, translate into an 17% drop in Tobin's average q . This corresponds to a third of the observed drop in q of the mid 1970s . Our model is qualitatively consistent not only with the data patterns in equity

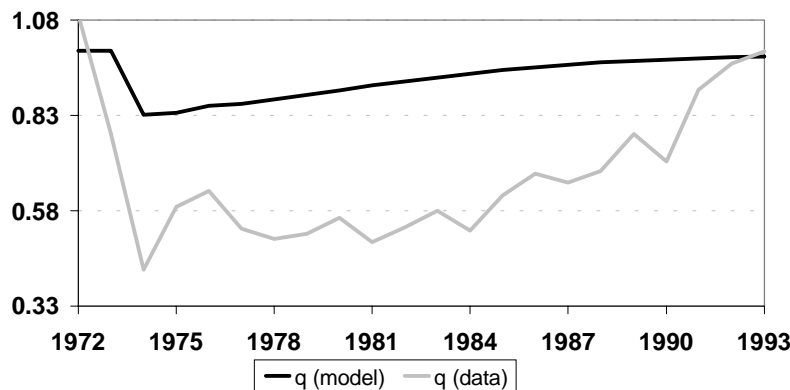


Figure 6: Tobin's q (energy crisis): Model vs data

prices, but also with the economic slowdown of the mid 1970s.

The basic economic mechanism we considered is the following: A sudden increase in energy prices renders old capital obsolete, and causes its market valuation to collapse. Old technologies are abandoned and gradually replaced by energy saving ones, better suited for the new economic conditions. Old capital is left to depreciate, and labor flows from the old to the new type of technology. The replacement process is gradual, and market values recover in a smooth fashion.

We have assumed the energy-efficient technology arrives simultaneous, and exogenously, with the energy price shock. We believe, though, that the introduction of an energy saving technology can be easily endogenized using the induced innovation hypothesis. If the adoption of a new technology is always available, but costly, it is possible that agents do not introduce it unless the economic conditions demand it. We believe that the energy price increase of 1973-74 gave agents enough incentives to pay the cost, and to develop such an energy saving technology.

Our analysis indicates that changes in energy prices should be part of any theory of the stock market collapse of 1973-74.

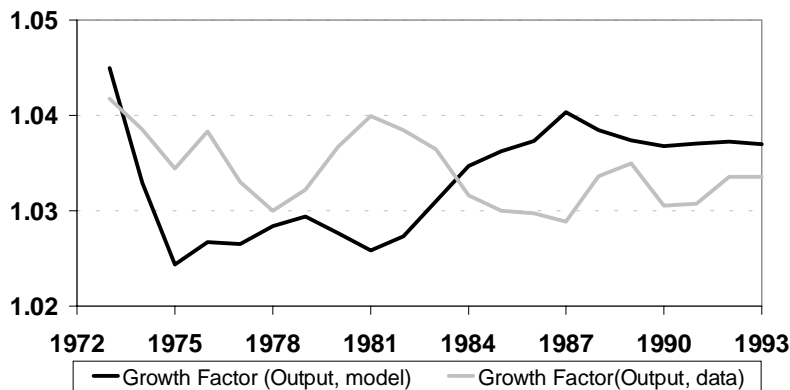


Figure 7: Output growth (energy crisis): Model vs data

5 Data Appendix

Here we outline how the major series used in the figures were constructed.

Figure 1. Ratio of Market Value to Replacement Cost of Tangible Assets for Corporations

Market value of corporations was constructed using data from the *Flow of Funds Accounts of the United States* (FOF) issued by the Board of Governors of the Federal Reserve System (FRB).² In FFA, domestic corporations are divided into nonfinancial and financial corporate business. Financial corporations are further divided to the following categories as listed in Table F.213: Commercial banking, life insurance companies, other insurance companies, closed-end funds, exchange-traded funds, real estate investment trusts (REITs) and brokers and dealers.

Our measure of market value reflects both equity value and debt of all domestic corporations, and all direct or indirect (through mutual funds) intercorporate holdings of corporate equity and debt has been netted out. To that effect market value of domestic corporations (MV) has been constructed

²This data can be downloaded from the FRB website at <http://www.federalreserve.gov/releases/z1/current/data.htm>.

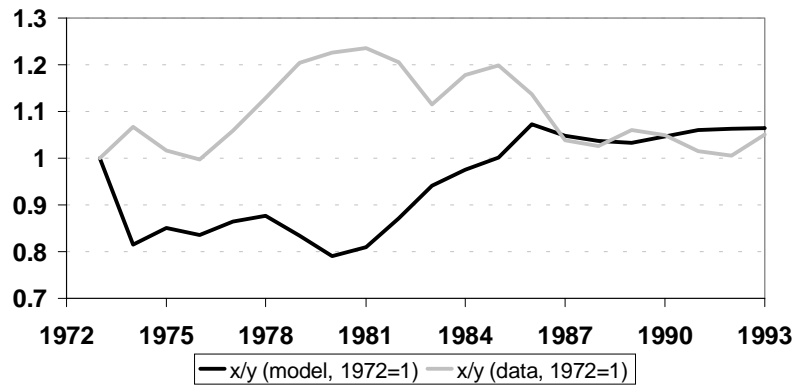


Figure 8: Corporate investment to output (energy crisis): Model vs data

as follows:

$$\begin{aligned}
 MV = & \text{Corporate equity issued by nonfinancial corp. business (Table L.213 Line 2)} \\
 & + \text{Corporate equity issued by financial corp. (Table L.213 Line 4)} \\
 & + \text{Total liabilities of nonfarm nonfinancial corp. business (Table L.102 Line 20)} \\
 & - \text{Total financial assets of security brokers and dealers (Table L.130 Line 1)}
 \end{aligned}$$

- Total financial assets of nonfarm nonfinancial corp. business (Table L.102 Line 1)
- + Total liabilities of commercial banking (Table L.109 Line 21)
- Total financial assets of commercial banking (Table L.109 Line 1)
- + Total liabilities of life insurance companies (Table L.117 Line 16)
- Total financial assets of life insurance companies (Table L.117 Line 1)
- + Total liabilities of other insurance companies (Table L.118 Line 14)
- Total financial assets of other insurance companies (Table L.118 Line 1)
- + Total liabilities of closed-end funds (Table L.123 Line 7)
- Total financial assets of closed-end funds (Table L.123 Line 1)
- + Total liabilities of exchange-traded funds (Table L.123 Line 13)
- Total financial assets of exchange-traded funds (Table L.123 Line 8)
- + Total liabilities of REITs (Table L.129 Line 11)
- Total financial assets of REITs (Table L.129 Line 1)
- + Total liabilities of security brokers and dealers (Table L.130 Line 13)

Replacement cost of tangible assets of corporations was constructed using data from the *Fixed Assets Tables* (FA) reported by the Bureau of Economic Analysis (BEA)³ and also from the FOF. Our measure of tangible assets include all nonresidential and residential fixed assets, plus inventories. Corporate fixed assets are the sum of corporate nonresidential fixed assets (FA Table 4.1 Line 13) and corporate residential fixed assets (FA Table 5.1 Line 3). Stock of inventories held by nonfarm nonfinancial corporations is from FOF Table B.102 Line 5. We assume financial corporations hold no inventories as their inventory investment is zero in the product account, and we neglect inventories hold by farm corporations since they are negligibly small.

Figure 2. Energy Prices relative to the GDP Deflator

We by and large the methodology outlined in Atkeson & Kehoe [2] and construct an energy price deflator from a weighted average of coal, natural

³This data can be downloaded from the BEA website at <http://www.bea.doc.gov/bea/dn/faweb/AllFATables.asp>.

gas, petroleum and electricity consumed in the commercial, industrial and the transportations sectors. This excludes residential consumption as we focus only on the business sector and also energy consumed by the electric power sector as in our model all energy is imported. We use quantity and price data reported in the Annual Energy Review (AER) 2001.⁴ The quantity of each type of energy (measured in units of Btu) consumed in the commercial, industrial and the transportation sectors are from Tables 2.1c, 2.1d, 2.1e respectively. For prices we use consumer price estimates of energy (as businesses are consumers of energy) reported in Table 3.3 and we label the price of energy for each type as P_i . For each type of energy i , we add the consumption of that energy type in all sectors and call that Q_i . Then, total energy expenditure is simply $\sum_i Q_{it}P_{it}$. We calculate real energy use using 1972 prices as the base year. Hence real energy use equals to $\sum_i Q_{it}P_{i1972}$. The energy price deflator P_t is simply the ratio of the total energy expenditure to total energy use:

$$P_t = \frac{\sum_i Q_{it}P_{it}}{\sum_i Q_{it}P_{i1972}}$$

The GDP deflator is constructed in the usual way from nominal and real GDP series reported in BEA's NIPA Tables 1.1 and 1.2.

Figure 3. Energy Expenditure and Use in the Business Sector

Total energy expenditures of the business sector was calculated as in Figure 3 and then was divided by the nominal GDP of the business sector (BEA's NIPA Table 1.7). The total real energy use of the business sector (expenditure using 1972 prices) was calculated as explained for Figure 3. This number was divided by the real GDP of the business sector in 1972 prices. Real GDP of the business sector data is from BEA's NIPA Table 1.8. These numbers are reported in 1996 dollars. We first construct a price deflator using nominal and real GDP of the business sector, readjust the level of the deflator such that $1972 = 1$ rather than 1996. Then we multiply this number with nominal GDP of business to get real GDP of business in

⁴This data can be downloaded from the EIA website at <http://www.eia.doe.gov/emeu/aer/contents.html>.

1972 dollars.

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